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ON THE CORRELATION OF VISUAL-MOTOR REACTION TIMES AND LIGHT SENSITIVITY

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ABSTRACT: The purpose of this article is investigation of the correlation of two characteristics of human psychic activity--visual-motor reaction times and light sensitivity. Comparison of data concerning motor reaction time and visual sensation thresholds (on the horizontal meridian of the retina) indicates the existance of a certain functional relationship between these indices: to an increase in visual sensation thresholds, as a rule, corresponds the prolongation of relatent periods of visual-motor reactions, and vice versa. Visual acuteness, as we know, is based psychologically on the so-called resolution capacity of the eye, which in the final analysis hinges on the density of light-sensitive nerve endings. Thus our hypothesis of the action of the force wall is indirectly verified by this fact.

INTRODUCTION

The principal objective of this investigation is the correlation of two vitally important characteristics of the psychic activity of man which became the object of psychological analysis, so to speak, since the inception of psychology as a science. We have in mind the question of the correlation of reaction times and sensitivity. Before going into the exact formulation of the task of the experimental part of this work we will discuss briefly the stated psychological objectives separately and independently, as has been done in psychology until recently. /97*

Reaction time is one of the oldest objects of experimental-psychological analysis. W. Wundt, who built the first psychological laboratory, analyzed both sensations and reaction times, the main objectives of his program.

Soon afterward, analysis of the latent periods of motor reactions became the main branch of an entire field of psychology, called psychometry. A method

*Numbers in the margin indicate foreign pagination.

of measuring reaction times was proposed by Helmholtz (1850), and then developed by Donders, Ekoner, W. Wundt, and occupied an important position in the works of such psychologists as L. Lange (1888), N. N. Lange (1893), A. A. Tokarskiy (1869), K. N. Kornilov (1922), among others.

Reaction time was used extensively in psychometry for global characterization of complex psychic processes (recognition, discrimination, choice). Further development of this method showed it not to correspond to the initially stated far reaching problems. Nevertheless the length of the latent period of motor reactions is still used, along with other indices, as an important element of objective characterization of complex psychic activity.

Analysis of the rate of reactions is important because it is involved in the vast region of psychological analysis of the forms and means of human response to certain stimuli. This region of analysis encompasses the problems of mastering new actions, acquisition and strengthening of habits and many others.

The second important aspect of analysis of reaction times consists in the fact that variations of the latent period may be an accurate index of the dynamics of psychic activity. And in this sense the index of the speed of reaction is /98
used in many contemporary analyses: analysis of certain features of psychic activity of children (in the laboratories of Professor A. G. Ivanov-Smolenskiy [6] and N. I. Krasnogorskiy [8]); analysis of mental processes in adults (in the laboratory of Ye. I. Boyko [1]), analysis of the features of athletic activity (A. N. Krestovnikov [9], Z. I. Biryukov among others).

Finally, the problem of reaction speed may be important in analysis of the forms of the human activity in which certain actions or operations must be performed as quickly as possible. This is particularly important in special branches of psychology, particularly psychology of labor.

Turning now to the problem of sensitivity, we should focus attention on the tremendous importance of this problem in general psychology on the one hand and on its practical importance on the other.

Sensitivity as a value inverse to a threshold, a measurable index of sensations caused by weak stimuli (or fine differences between sensations), makes it possible to apply an objective measure to analysis of human sensory processes.

It was not by chance, therefore, that scientific analysis of sensations became possible with the discovery of the so-called Weber-Fechner fundamental psychophysical wall, i.e., along with the statement of the problem of distinctive sensitivity. At this time the total number of works pertaining to factors that influence the different forms of sensitivity is very large. At the same time, as happened in the analysis of reaction times, sensitivity began to be used more and more as the index of various aspects of human psychic activity. In this second connection we should mention the studies of O. A. Dolin [5], K. Kh. Kekcheyev [7], B. M. Teplov's co-workers [10], among others.

The purpose of this investigation, as stated above, was the correlation or internal relationship between sensitivity and reaction time.

In order to resolve the stated problem it was necessary to compare these two indices in the presence of action on the same analyzer. The first step was to trace the simultaneous change in sensitivity and reaction time with a change in the conditions of stimulation. The stated comparison was made on the human visual analyzer, proceeding from the fact, knowing psychology, of change of both reaction time and sensation thresholds when the location of ths stimulus in the field of vision is change. In order to prove that a certain functional relationship exists between the stated indices we first had to establish that by changing the locus of the stimulus in the visual field we obtain simultaneous and opposite changes in the visual-motor time and light sensitivity.

There are certain data and pertinent literature concerning the change of reaction time as a function of the location of the stimulus in the field of vision. Thus, Hall and Kries [11], analyzing points moved 30° and 60° upward, downward, to the right and to the left toward the periphery from the center of the retina, made the following discoveries:

1) The farther from the fovea centralis a stimulus acts, the longer the reaction time;

2) The reaction time is shorter from the top in relation to the bottom part of the retina and from the nose in relation to the temporal part.

Poffenberger (1912) [12] analyzed the reaction time to stimuli in the /99 lateral field of vision on the horizontal meridian at distances of 3, 10, 30 and 45° from the center. He found that, excluding stimulus at 3°, the increase of reaction time to the periphery during temporal stimulation is substantially larger compared to nasal stimulation.

In 1955 Slater-Hammel [13] published in Washington a work on the problem of reaction time from peripheral parts of the field of vision. The principal premises of this work are the following:

1) Reaction time increases as the stimulus is removed from the point of direct vision;

2) The direction of withdrawal of the stimulus from the center of the visual field is unimportant;

3) The time of reaction to a stimulus perceived directly exceeds the relative index of the speed of reaction to a stimulus indirectly perceived.

Special studies have also been done on the problem of fluctuations of light sensitivity during stimulation of various parts of the retina. In particular the co-workers of the Leningrad State Optical Institute, Gassovskiy and Nikol'skaya [3], and also Gassovskiy and Kahokhlova [4], have been working on this problem. These authors analyzed the comparatively large region of the retina (up to 12° from the fovea on the horizontal meridian in the nasal direction and up to 26% from the fovea in the temporal direction). Nevertheless, their data indicate that after a slight increase the sensitivity drops sharply toward the periphery of the retina.

Also found in the literature are data concerning the correlation between the reaction time and various points of the retina and different passage perceive form and also to distinguish closely situated objects (index of visual acuteness) [2].

According to Poffenberger, as already mentioned above, the reaction time increases from the center of the field of vision to the periphery, and is greater in the temporal part of the retina than in the nasal. The acuteness of vision, according to experimental data, also increases by measure of distance from the fovea, and specifically it is greater in the nasal half of the retina than in the temporal.

This correspondence prompted a number of foreign investigators to make a conclusion concerning the dependence of reaction time on visual acuteness. It seems thus, however, that if the above stated correlation is considered established, it is still difficult to understand the functional relationship between reaction time and visual acuteness on the basis of existing phsyiological evidence.

The fundamental points of the hypothesis which we advance concerning the functional correlation between reaction time and light sensitivity consists in the following. As we know, the level of sensitivity at any point of the retina of the eye depends on the number and distribution of light-sensitive nerve endings. The correlation between this moment and the reaction time can be understood from the point of view of the known "force wall".

According to this law the stronger stimulus should produce a faster reaction.

If a correlation actually exists between a relatively high sensitivity and relatively short reaction time, it can be understood as a result of the fact that stimuli of the objectively equal force are perceived differently by different parts of the retina in accordance with their changing level of reactivity, and specifically; the force of the stimulus would be greater for points of higher reactivity than for points of relatively lower reactivity.

Procedure /100

In accordance with the above stated hypothesis, the time of motor reactions in response to visual stimuli appearing in different parts of the field of vision is related to the changing level of reactivity of various points of the visual analyzer.

An experimental check of this hypothesis could be made by measuring the visual-motor reaction times, on the one hand, and thresholds of visual sensations, on the other hand, in the same parts of the retina.

Thus we were faced with two specific problems:

1) To measure the motor reaction times in response to stimuli addressed to several selected points of the retina and

2) to determine the absolute thresholds of sensations with stimulation of the same points of the retina.

In both cases the experimental procedure had a number of specific and a number of common points. We will first discuss the differences in tests on the measurement of reaction time and determination of sensitivity.

The problem of determining the difference in reaction time as a function of the point of stimulus in the visual field forced us from the very start to satisfy one fundamental procedural requirement: all reaction time measurement conditions, except the location of the stimulus on the retina of the eye, must be as equal as possible. This means first of all the need for physical equality of the variously located light stimuli cast on the tested eye. To satisfy this condition we used a special atmospheric perimeter on whose interior surface were located the light sources. The right eye of the test subject was placed in the center of the hemisphere. Here, after establishing equal initial brightness of the light sources, we had equal distance to the eye of the test subject, equal shape and dimensions. To be certain of equal initial brightness of the stimuli we used in this series of tests the same light source, which we moved over the interior surface of the perimeter.

According to instruction, the test subject was to press as uniformly and as fast as possible a reaction button under his right hand when the light appeared in the field of vision.

One eye (the right) was exposed to the light stimuli, while the other was covered. The initial position of the working eye was fixation on a red light in the center of the hemisphere.

During measurement of reaction time the subject's head was held as still as possible on a chin rest attached to the center of the hemisphere.

The reaction time of the test subject was recorded by an electric stopwatch in hundredths of a second.

For measuring sensitivity we used S. V. Kravkov's adaptometer. With this instrument we obtained at a distance of about 1.5 meter in front of the test subject's eye a reflection of the light spot. The brightness of the spot was changed in a broad range by means of a photometric wedge.

Change of the position of the light spot in the field of vision and its aiming onto the required part of the retina were accomplished by moving the red reference point, attached to a movable support, along the periphery. Thus the light spot itself, in view of technical test conditions, remained fixed. The eye of the test subject was placed in the center of this circle, around which the reference point was moved during the test.

Before the test, the test subject was instructed to look at the red point signal "attention" and say "I see" as soon as he saw the light spot to the right of the point and then to say "I do not see" as soon as he ceased to see the spot.

The numerical graduations of the photometric wedge at which the test subject just noticed and just ceased to see the spot were recorded by the experimenter. The arithmetic mean of these values was translated in tabular form into units of light penetrability and used as the sensitivity index.

With respect to the other aspects of the procedure it should be mentioned that the procedure was determined primarily by the need for maximum equality of experimental conditions during measurement of motor reaction times and for determination of sensitivity thresholds. Particularly important here are factors that influence the level of visual sensitivity, especially lighting conditions.

In our tests the thresholds of visual sensitivity during stimulation of points of the retina were measured in darkness after a 45 minute darkness adaptation period. The same conditions were maintained during measurement of motor reaction times.

The sensitivity and motor reaction time measurements were made with the stimulus in 9 different points of the field of vision on the horizontal meridian and to the right. The stimulated points were located at distances of 3°, 10°, 20°, 30°, 40°, 50°, 60°, 70° and 80° from fovea centralis.

Former investigators (Gassovskiy and Nikol'skaya; Gassovskiy and Kahokhlova) /101
were interested in a comparatively small portion of the retina: they analyzed points lying in the retina on the horizontal meridian in the nasal direction up to 12° to the periphery from the fovea and in the temporal direction to 20-26°

from the fovea. It is noteworthy here that the stated reagion of the retina was analyzed in detail and the findings were completely unambigious.

We measured the sensitivity of the retina in other points, because our task was somewhat different: we wanted to explain the greatest differences in sensitivity oscillations during stimulation of various points of the retina, since only in this case could a comparison with the functioning of these points of the retina in the make-up of visual-motor reactions be sufficiently expressive. Therefore we placed most of the stimuli at 10° intervals.

The next group of procedural conditions consisted in a system of administration of stimuli.

The time intervals between individual measurements of sensitivity were 40-60 seconds (the measurements were made 1 time every 1 1/2 to 2 minutes). In tests to determine the reaction times the intervals between individual measurements were also set at 40 seconds. This was quite sufficient to exclude, for all practical purposes, the effect of subsequent reactions.

Special attention was devoted to the "preparedness factor" of the test subject to react at the moment of reaction to his stimuli. Using the preliminary "attention" we established the preliminary period, which in our tests was about 2 1/2 seconds.

To preclude the possibility of reaction to a certain time interval we used the so-called "emthod of check tests".

The essence of this test is that the experimentor gives the "attention" signal from time to time but does not give the light stimulus. This method discloses whether or not the test subject reacted to something other than the light signal.

Each test, including the adaption time, lasted for about 2 hours.

In order to level off somewhat the effect of darkness on the data obtained, measurments were made alternately: once starting at the point nearest the center (3°), toward the periphery, and then another just the opposite, from the farthest point (80°) to the center.

Six adult test subjects were put through all tests.

Discussion Of Results

Turning to analysis of the findings, we will first examine separately the data concerning the sensitivity and motor reaction times, and then we will /102 correlate them.

In order to represent the data from sensitivity analysis in practical form we portray the relation of the sensation thresholds at the examined points of the retina in the form of curves (Figure 1), plotted according to the following principle: the abscissa axis corresponds to the horizontal meridian in the field of vision, on which the light stimuli are located 3, 10, 20°, etc., from the fovea; on the ordinate axis are laid out the sensitivity indices of a given point in threshold values. Thus the convergence of the curve plotted by this principle on the abscissa axis indicates a lowering of the threshold at the corresponding point of the retina, and divergence from the axis--lathing of the threshold.

Six adults were subjected to testing. Since the readings thus obtained were sufficiently unambiguous, the graphs of only three of the test subjects are presented below.

First, as can be seen by examining the curves, is the fact that by measure of distance from the central point they first have a tendency to fall in a wavy manner, and then, starting usually at 30° of the periphery, there is a more or less steep rise. This means that the sensitivity on moving to the center to the periphery first increases somewhat and begins to fall only at about 30°. At 40° to 50° the curves climb very steeply, indicating a pronounced reduction of sensitivity.

As regards the segment from 3 to 30°, here our data, at first glance, do not indicate a completely unambiguous role.

First of all the curves of nearly all the test subjects show a sudden upward jump (ovation of thresholds)--10° for some and 20° for others.

Since these jumps occur at different points on the curves of different test subjects, the overall similarity for these curves would appear to be violated.

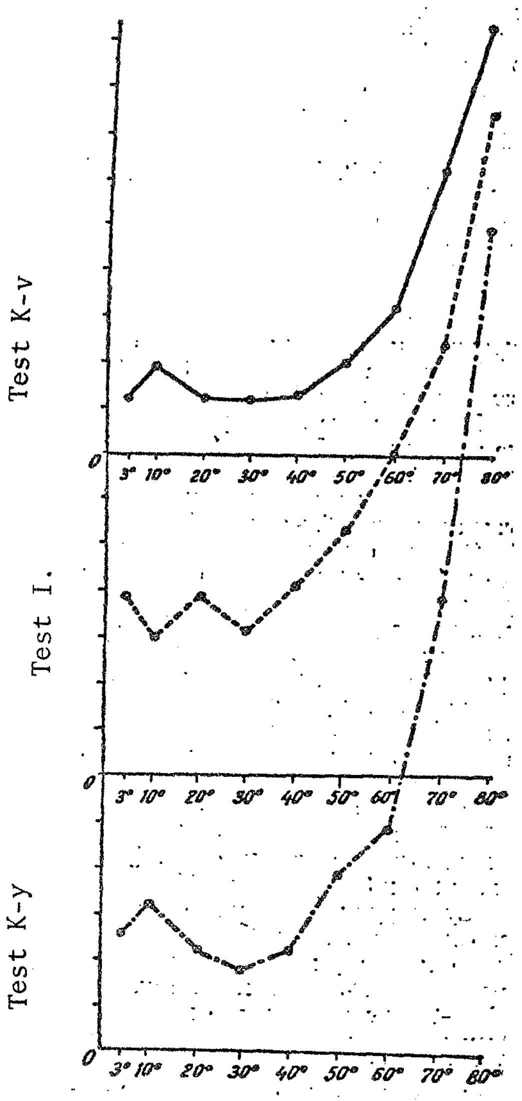

Figure 1: Changes of Thresholds of Visual Sensations During Movement of Stimulus on Horizontal Meridian in Right Half of Field of Vision.

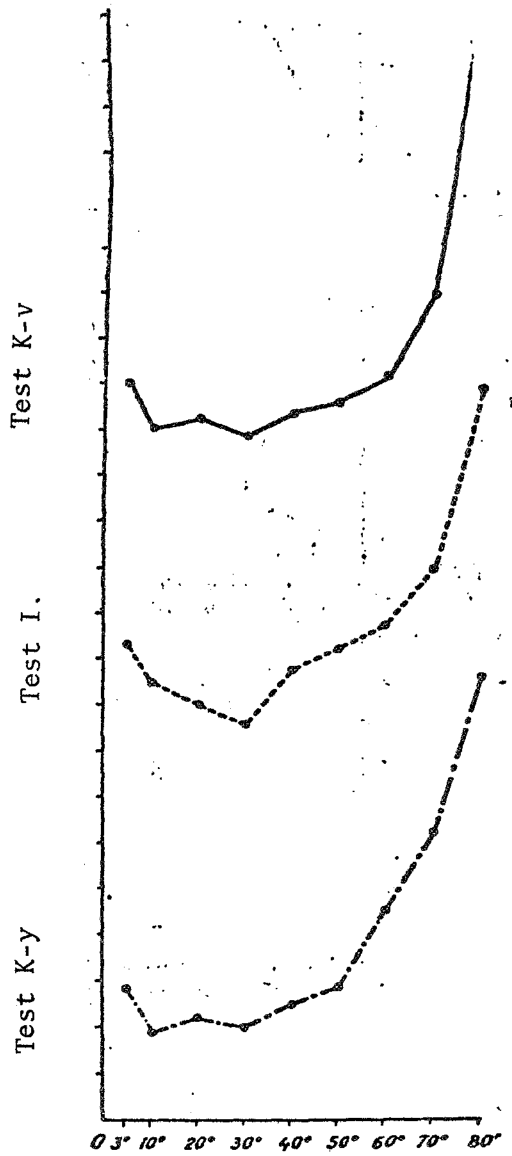

Figure 2: Change of Visual-Motor Reaction Time as Stimulus Moves on Horizontal Meridian in Right Half of Field of Vision.

Recalling, however, that the blind spot is located precisely in this region of the retina (12°-18° on the horizontal meridian in the nasal direction), the stated change of the thresholds becomes clearer. Our stimulus apparently struck the zone adjacent to the blind spot, and it could vary in test subjects with respect to both magnitude and shape. Perhaps this is the reason the stated jumps on the sensitivity curves of the various test subjects appear differently and at different points. If, on the basis of the above explination, we exclude from examination the oscillations of sensitivity in the 10° and 20° zones, then there is no doubt about the general similarity of the curves obtained, specifically: on transition from the point nearest the center (3°) to the periphery the curve converges noticeably on the abscissa axis, and this convergence is most distinct in the region between 20° and 30° (rarely at 10° of the periphery).

Summarizing all that has been stated on the given subject, it may be assumed that the change of light sensitivity as the stimulus moves on the horizontal meridian of the nasal part of the retina is such that on transition from the point nearest the center the sensitivity increases sharply toward 20°-30° of the periphery, or the region of lowest thresholds; then, there is a discontinuity in the curve and it begins to diverge from the abscissa axis, i.e., the sensitivity decreases. From 30° and 40°-50° the reduction of sensitivity is slight; from 40°-50° the drop of sensitivity, as a rule, is very sharp.

What data were obtained concerning motor reaction times?

The results of reaction time meeasurements during stimulation of different points of the retina are also presented in the form of graphs, the plotting /103
principle which is the same as those of sensitivity. The difference is that instead of values characterizing sensation thresholds the motor reaction time indices are plotted on the ordinate axis. A drop of the curve indicates shorter reaction time, and a rise longer reaction time.

Analysis of the curve (Figure 2) compels recognition that all the basic features noted during examination of the curves of change of the thresholds are also present here: from the central point (3°) the curve of reaction time drops sharply; the region where the latent period is maximum falls at 10°-30° of the periphery, and, finally, from 40°-50° the curve rises sharply upward.

It should be pointed out, however, that in certain cases the curves of change of thresholds appear to rise more steeply than the curves of reaction time. This can be explained, however, by the fact that the units of measurement used in these two cases are different. In other words, the noted difference in the steepness of the curves may depend on the actually random and in both cases different scale on which the curves were plotted.

Thus preliminary separate analysis of the data on analysis of sensitivity and motor reaction time lead us to recognize the possibility of correlating these data. And if as a result of such correlation we establish the fact of simultaneous, but opposite (with respect to sine) change of sensitivity and motor reaction time (after changing the point of stimulus on the retina of the eye), then, in our opinion, this will be grounds for considering the existance of a /104
functional relationship between both phenomena proved.

To check and then demonstrate that the above mentioned simultaneous change of both phenomena actually occurs, we compared the data concerning the reaction time and sensation thresholds on the same graphs (Figure 3).

The sensation thresholds obtained by locating the stimulus at distances / 105
of 3°, 10°, 20°, 30° from the central point on the horizontal meridian of the right side of the field of vision are plotted successively on the abscissa axis (away from the origin). The reaction times during stimulation of the same points of the retina and in the same sequence are plotted on the ordinate axis.

The curves, plotted on coordinate points, of all test subjects reveal a certain accuracy, indicating that there is certain functional relationship between the investigated phenomena (motor reaction time and sensitivity).

At the same time, the curves plotted on our graphs are not straight. This means that the relationship between reaction time and sensitivity is not linear. On the basis of the general form of the curve, we assumed that the function of interest to us is algorithmic. To prove this assumption we took the algorithm of the values obtained during determination of the sensation thresholds and replotted the graphs of the correlation between reaction time and the algorithm of the thresholds (Figure 4).

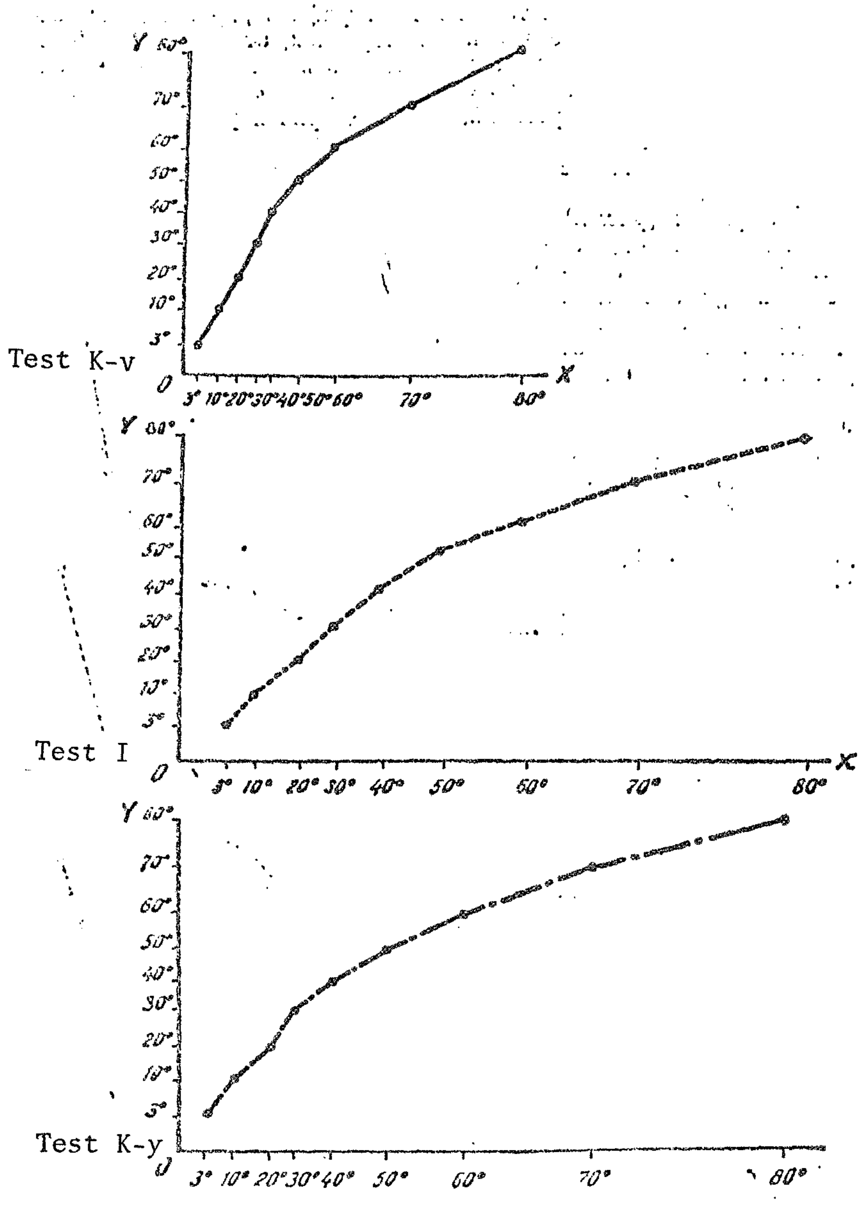

Figure 3: Relationship Between Visual-Motor
Reaction Time and Thresholds of Visual Sensations.

The curves plotted on the coordinate points are very close to straight lines. Consequently we were correct in assuming that the above curves of the relationship between motor reaction time and sensitivity are algorithmic and the dependence of the latent reaction period on sensitivity is an algorithmic function.

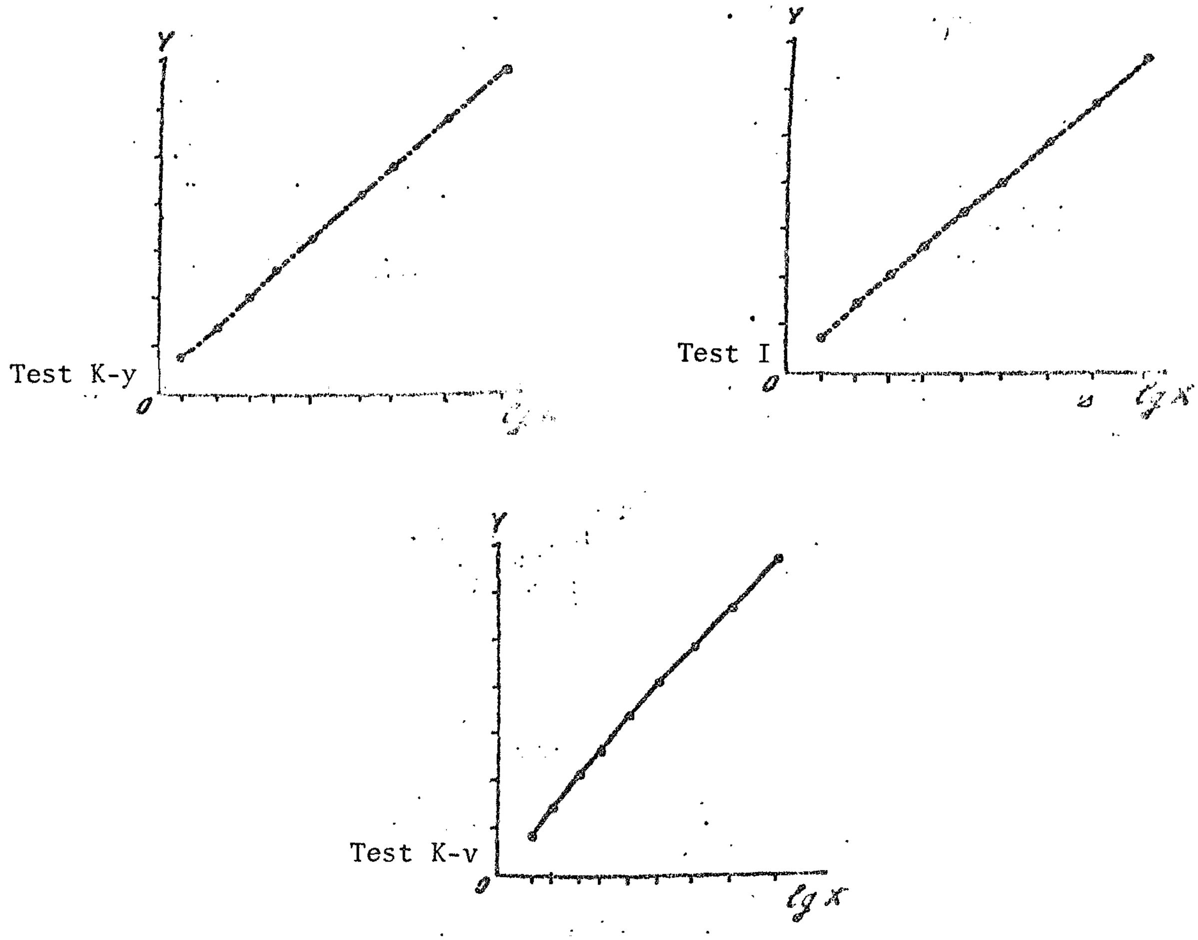

Figure 4: Relationship Between Visual Motor Reaction Time and Algorithms of Visual Sensation Thresholds.

Conclusions

Comparison of data concerning motor reaction time and visual sensation thresholds (on the horizontal meridian of the retina) indicates the existence of a certain functional relationship between these indices: to an increase in visual sensation thresholds, as a rule, corresponds the prolongation of relatent periods of visual-motor reactions, and vice versa.

It must be assumed that the difference in the time of motor reactions when stimulating various points of the visual system with light is related to distribution of the light sensitive elements on the retina. Where these elements are densest and sensitivity highest, reaction time will be shortest and conversely. This suggests that there is between the visual motor reaction time and sensitivity a functional relationship which is most readily understood from the point of view of the known psychological "force wall".

Correlation with visual acuteness, which was established by former researchers, can also be interpreted on the basis of our findings. Visual acuteness, as we know, is based psychologically on the so-called resolution capacity of the eye, which in the final analysis hinges on the density of light-sensitive nerve endings. Thus our hypothesis of the action of the force wall is indirectly verified by this fact.

REFERENCES

1. Boyko, Ye. I. (editor), *Materialy k Izucheniyu Uslovno-Reflektornykh Osnov Psikhicheskoy Deyatel'nosti Cheloveka (sb. eksperimental' nykh rabot)* [Materials on Analysis of Condition Reflex Principles of Psychic Human Activity (A Collection of Experimental Works)], *Izvestiya APN RSFSR*, No. 53, Moscow, APN RSFSR Press, 1954.
2. Vudvorts, R., *Eksperimental'naya Psikhologiya* [Experimental Psychology], Moscow, Foreign Literature Press, 1950.
3. Gassovskiy, L. N. and N. A. Nikol'skaya, "Distribution of Light Sensitivity in Peripheral Part of Retina," *Sovetskiy Vestnik Oftal'mologii*, Vol. 9, No. 2, 1936.
4. Gassovskiy, L. N. and A. N. Khokhlova, "On the Problem of Distribution of Sensitivity of Peripheral Part of Retina to White Light," *Sovetskiy Vestnik Oftal'mologii*, Vol. 9, No. 2, 1936.
5. Dolin, O. A., "New Facts on Psychological Understanding of Human Association (Photochemical Conditioned Reflex from the Eye)," *Arkhiv Biologicheskikh Nauk*, Vol. 42, Nos. 1-2, 1936.
6. Ivanov-Smolenskiy, A. G. (editor), *Eksperimental'nyye Issledonoviya Vysshey Nervnoy Deyatel'nosti Rebenka* [Experimental Investigations of Higher Nervous Activity of Children], Collections 1-5, 1930-1940.
7. Kekcheyev, K. Kh., *Nochnoye Zreniye* [Nocturnal Vision], Moscow, 1942.
8. Krasnogorskiy, N. I., *Trudy po Izucheniyu Vysshey Nervnoy Deyatel'nosti Cheloveka i Zhivotnyikh* [Proceedings on Analysis of Higher Nervous Activity of Man and Animals], Vol. 1, Moscow, "Medgiz Press", 1954.
9. Krestovnikov, A. N., "Study of Higher Nervous Activity as the Basis of the Theory of Physical Learning," *Zhurnal Vysshey Nervnoy Deyatel'nosti Imeni I. P. Pavlov*, Vol. III, No. 5, 1953.
10. Teplov, B. M. (editor), *Tipologicheskiye Osobennlesti Vysshey Nervnoy Deyatel'nosti Cheloveka* [Typological Features of Human Higher Nervous Activity], Moscow, APN RFSFS Press, 1956.
11. Hall, G. S. and J. V. Kries, *Archiv. fur Anatomie und Physiologie* [Archives for Anatomy and Physiology], 1879.
12. Poffenberger, A. T., *Archives of Psychology*, 1912.
13. Slater-Hammel, A. T., *Research Quarterly of the American Association for Health, Physical Education and Recreation*, Vol. 25, No. 1, 1954.

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